Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone

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Grant #: N000149710279
http://blg.oce.orst.edu/shoaling

LONG-TERM GOAL

Our long term goals are to improve parameterization of surface fluxes in the coastal zone in the presence of wave growth, shoaling, and internal boundary layer development. These goals include improving the present form of similarity theory used by models to predict surface fluxes and stress over water surfaces and documenting development of internal boundary layers in the coastal zone that are currently not modelled correctly, particularly in cases of flow of warm air over colder water.

OBJECTIVES

Our objectives are to provide quality controlled data sets which include spatial variation of surface fluxes, stress and wave characteristics and provide vertical structure of the wind and thermodynamic variables in the coastal zone. The objectives also include both evaluation of present formulations for surface fluxes at the air-sea interface and evaluation of model simulations of internal boundary layer development.

APPROACH

The first approach has been implementation of an extensive literature survey on existing studies of air-sea interaction in the coastal zone and internal boundary layer development. The second approach is implementation of three field programs, one completed in fall of 1997, one completed in spring of 1999 and one in fall of 1999. The spring 1999 field program was designed to study the internal boundary layer in offshore flow, particularly in stable conditions. The third approach is data analysis and evaluation of existing boundary layer and surface flux formulations. The fourth approach is model comparisons with other groups.

WORK COMPLETED

During the past year, we have concentrated on very stable conditions primarily related to flow of warm air over cold water. We have made additional progress with joint modeling studies of offshore flow with James Doyle of NRL-Monterey.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **College of Oceanic and Atmospheric Sciences,,Oregon State University,,Corvallis,,OR, 97331**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

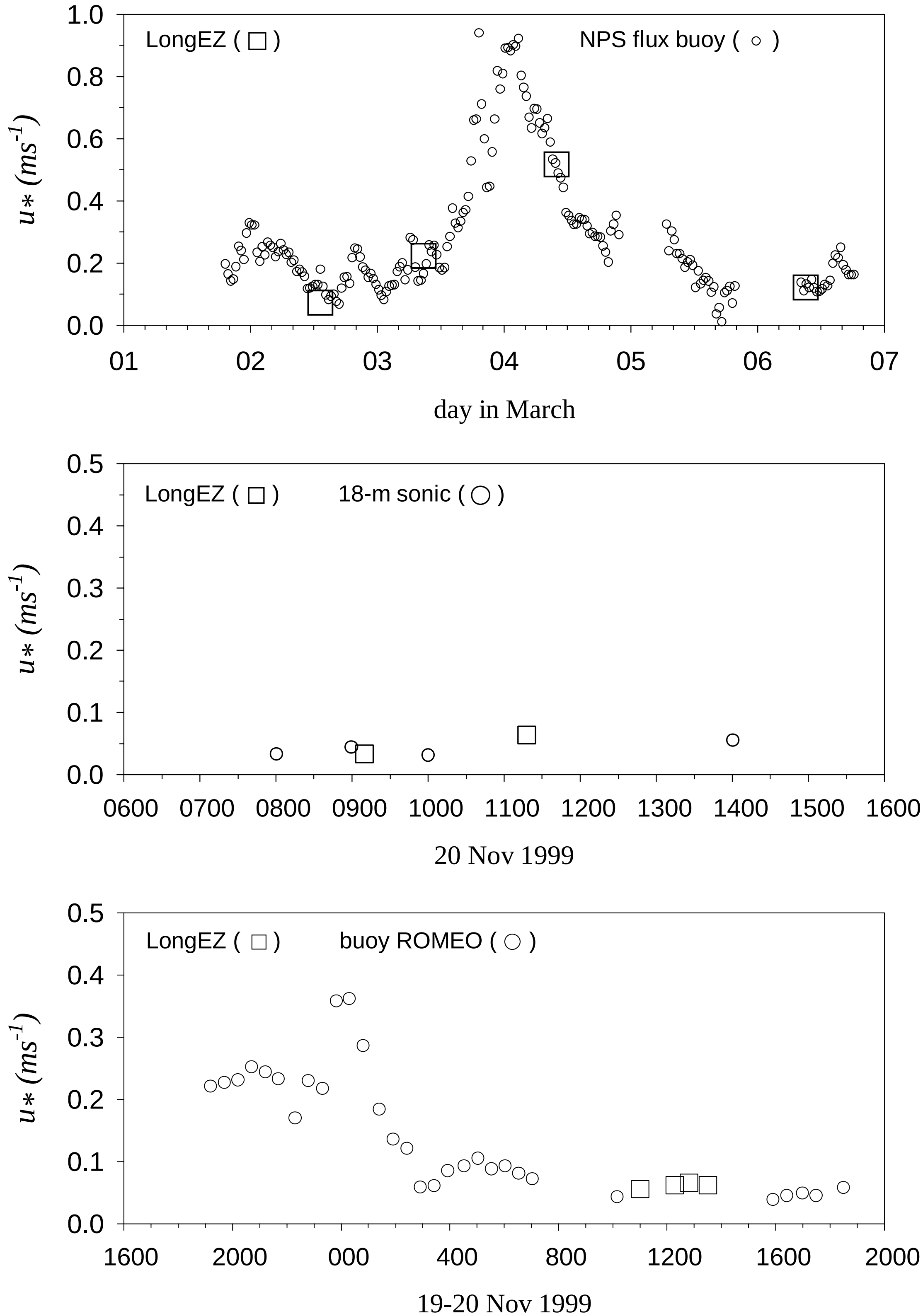

Figure 1. {a) Comparison between the friction velocity for the LongEZ and the NPS buoy for the period of overlapping observations in March 1999, b) comparison between the LongEZ friction velocity and that for the 18-m sonic anemometer on 20 November 1999 and c) comparison between the LongEZ friction velocity and that for buoy Romeo on 20 November 1999.

RESULTS

Analysis of LongEZ aircraft data and our SHOWEX sonic anemometer data reveal frequent occurrence of very small surface stress and roughness lengths. These very small roughness lengths with near collapse of the turbulence are generally associated with advection of warmer air from land over colder water. Numerical estimates of the aerodynamic roughness length may be subject to large errors for weak surface fluxes in very thin boundary layers because of significant random flux errors, systematic small scale flux loss, errors due to fluctuations of the aircraft altitude and errors in the estimated mean wind speed by the aircraft. With very thin stable boundary layers, the stress may decrease significantly between the surface and the observational level. In this case, Monin-Obukhov similarity theory does not apply at the observation level and the roughness length computed from the data must compensate for this inapplicability. In spite of the above observational difficulties, the small values of the momentum flux inferred from the aircraft data also occur with sonic anemometer data collected from buoys and a tower at the end of a 570-m pier (Figure 1). Ultra-smooth values of the aerodynamic roughness length do not necessarily imply specific information on the wave state. The value of the aerodynamic roughness length only provides the correct flux at the observational height, given the specified stability functions, and its relationship to wave state in these cases is uncertain.

The influence of warm air advection extends the influence of land off the coast for tens of kilometers or more. The very small roughness lengths for stable conditions are partly due to reduction of the downward momentum flux by the stable stratification. The data also show the usual minimum of the roughness length and neutral drag coefficient for wind speeds of about 5 m/s. The larger values of the roughness length at weaker wind speeds are partly associated with large deviations of the stress direction from opposite to the wind vector, apparently due to the influence of swell. The very small roughness lengths are most likely to occur with a combination of intermediate wind speeds and stable stratification. Significant wind speed is required here to maintain the advection of warmer air over the cooler sea.

In some stable cases, the vertical transport of turbulence may be downward, implying that the main source of turbulence is above the surface-based stable layer. In these cases, the aerodynamic roughness length is much larger than that for the usual case of upward transport of turbulence energy. The multitude of physical influences on the surface stress and the difficulty of measuring weak momentum fluxes prevent categorical conclusions.

The joint modeling work with James Doyle and also “in-house” work indicates that existing mesoscale/regional models can simulate some aspects of offshore flow. Errors are largest for stable conditions associated with advection of warmer air over colder water. The model can simulate the formation of the very thin stable marine layer only with extremely fine vertical resolution, on the order of one meter. However the TKE models have not been able to simulate the shear-generation of turbulence at the top of the marine layer and downward transport of turbulence toward the sea surface. The restrictive format of the mixing length parameterization seems to be the primary source of the difficulties.

IMPACT/APPLICATION

Existing concepts of marine boundary layers and air-sea interaction are inadequate in very stable conditions associated with warm air advection over colder water. Existing boundary-layer models cannot simulate this case.

RELATED PROJECTS

Analysis of offshore tower eddy correlation data from two Scandanavian sites is being carried out under grant N00014-98-0282 from the Office of Naval Research. This data allows analysis of detailed vertical structure in the lowest 40 m whereas the above work concentrates on horizontal structure in the coastal zone.

SUMMARY

We have used fast response atmospheric measurements from a small low-flying research aircarft, a tower at the end of a pier and offshore buoys to study air-sea interaction in the coastal zone. The research aircraft also measures the wave field using three downward pointing lasers. Our analysis of this data indicates that the influence of shoaling waves is significant but less important than orginally thought. Nonetheless, compture models of air-sea interaction fail to properly account for the important influence of the surface wave state. Atmospheric flow of warm air over a colder sea surface can lead to complete collapse of the atmospheric turbulence and sea state. This collapse is not presently simulated in computer models.

PUBLICATIONS

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